On Saturday evening a lecture on the Transit of Venus was delivered by M. Faye, before a very large audience at the Cercle du Nord, a magnificent building, richly fitted up. The accomplished astronomer referred mostly to the arrangements at the French stations, deeply regretting that all civilised nations had not been united into a kind of federation for working in combination at a problem of such magnitude; he hopes that it will be so in 1882. He insisted upon the importance of photography, which has been used to such good purpose by the Americans, and he trusts that in future times photography will take the lead in such observations. He gave interesting details as to the Yokohama station, to which a Japanese prince educated in France will be attached as a photographer. The consequence will be that M. Jannsen and his associates will be admitted into the interior sea of Japan, where, up to the present moment, not a single foreign vessel has ever sailed.

Owing to the coincidence of the meeting of the British Association at Belfast, scarcely any English *savans* are present here. The only British member I have seen up to the present moment is Dr. Sylvester, the celebrated mathematician. He has been nominated the honorary president of his section, the acting president being M. Catalan, who, though a Frenchman, is regarded as a representative of Belgium. Ten years ago he settled in Liége, where he is a professor in the University.

The interest felt by the people generally is not nearly so great as in the case of the British Association in England. The inhabitants of the city do not appear to understand fully the extent of the honour conferred on them. A *train de plaisir* has been organised to visit distant workshops, but Lille workshops have not been opened for inspection.

Newspapers are glad to publish the transactions of the several sections, but the Association has not authorised any one of them to publish them at full length.

Last Saturday a most interesting experiment was tried with success on the Northern line. M. Giffard, the inventor of the injector, has constructed a new waggon which is suspended by powerful springs at both extremities, thus completely avoiding oscillation. It is very easy to read and even to write in these new carriages. The invention will be exhibited very shortly to the English public.

W. DE FONVIELLE

Lille, Aug. 23

OPENING ADDRESS BY THE PRESIDENT, M. WURTZ, AT THE MEETING OF THE FRENCH ASSOCIATION

The Theory of Atoms in the General Conception of the Universe

FRANCIS BACON conceived the idea of a society of men devoted to the culture of science. In his "New Atlantis," in which he describes the organisation of this society and its influence upon the destinies of a wisely governed people, he shows it rising to the dignity of a State institution. The progress of civilisation by the search for truth, and truth discovered in the order of nature by experiment and observation—such are the ends proposed and the means made use of. Thus, in an age when the syllogism was still supreme, and which was firmly held beneath the scholastic yoke, the English Chancellor assigned to science at once its true method and its mission in the world.

The plan of Bacon embraced all branches of human knowledge. The land was overrun by a multitude of observers, engaged, some in studying the monuments of the past, the language, the manners, the history of the nations; others in observing the configuration and the productions of the soil, noting the superficial structure of the globe and the traces of its revolutions, collecting all the data concerning nature, the organisation and distribution of plants and animals. Other men, located in various regions, cultivated the exact sciences. Towers were constructed for the observation of stars and meteors; vast edifices, arranged for the study of physical and mechanical laws, contained machines which supplied the deficiency of our forces, and instruments which added to the precision of the senses and rendered abstract demonstrations sensible. This immense labour was uninterrupted, co-ordinated, controlled; it had its origin in self-abnegation, it was regulated by precision, and had time for its sanction. Thus was it fruitful.

Such was the idea of Francis Bacon. To observe all things; by the rational comparison of these observations to disclose the hidden connections of phenomena, and to rise by induction to the discovery of their real nature and their causes, all with the view "of extending the empire of man over entire nature, and of executing everything possible for him to do;" such is the object which he has pointed out to us; such is the function of science.

This great exploration of the earth which he desired to institute, this patient and exact research of the laws of the universe, this deliberate intervention of science in the affairs of life and of the universe,—could all this be the work of his own time? He knew it too well to venture to hope it himself, and it is on this account, doubtless, that he placed the fortunate country which enjoyed so noble an institution in the solitude of the great ocean.

Two centuries and a half ago the conception of Bacon was regarded as a noble utopia; to-day it is a reality. That magnificent programme which he then drew out, is ours, gentlemen; ours, not in the narrow sense of the word, for I extend this programme to all who, in modern times and in all countries, give themselves to the search for truth, to all workers in science, humble or great, obscure or famous, who form in reality, in all parts of the globe and without distinction of nationality, that vast association which was the dream of Francis Bacon. Yes, science is now a neutral field, a commonwealth, placed in a serene region, far above the political arena, inaccessible, I wish I could say, to the strifes of parties and of peoples; in a word, this property is the patrimony of humanity. It is, too, the principal conquest of this century, which my illustrious predecessor characterised, with so much justice, as the century of science.

Modern generations are spectators, indeed, of a magnificent spectacle. For a century past the human mind has directed an immense effort to the study of the phenomena and the laws of the physical universe. Hence an astonishing development of all the sciences founded on observation and experiment. New ideas which have arisen in our days in the correlation and conservation of forces have been like a revelation to some of these sciences. Mechanics, physics, chemistry, physiology itself, have found at once a *point d'appui* and a bond of connection. And this powerful flight of ideas has been sustained by the progress of the methods, I should say by the more careful exactness of observations, the perfect delicacy of experiments, the more rigorous severity of deductions. These are the springs of this movement which hurry along the sciences, and of which we are the astonished and moved witnesses. It is to propagate it broadcast over our country that we hold, each year, this parliament, to which are invited all who take part or are interested in the war against the unknown. Science is indeed a war against the unknown; for, if in literature it is enough to give expression, and in art a body, to conceptions or beauties deposited either in the human mind or in nature, it is not so in science, where truth is deeply hidden. She must be conquered, she must be stolen, like the Promethean fire.

It is of some of these conquests that I wish to speak to-day, full of doubt and apprehension in presence of so great a task. To respond to the demands of his position and to follow noble examples, your president ought, at the beginning of this session and of the ceremonies which inaugurate our young association, to trace the progress accomplished in the sciences, mark by a few bold lines the various routes over which it has recently run, and the culminating points which it has attained. I shrink from such a programme: if it does not exceed the powers of some of my colleagues, and doubtless of some among you, it greatly surpasses mine. Less justified and less daring than was Condorcet at the end of last century, I only perceive the outlines and some bright patches of the sketch which he attempted to draw; and to see it accomplished, I shall call to my assistance those who will follow me in the honourable and perilous post I now occupy.

I shall confine myself, then, gentlemen, to speaking to you of what I know, or of what I think I know, by directing your attention to the science to which I have devoted my life.

Chemistry has not merely grown, it has been regenerated since Lavoisier. You know the work of that immortal master. His labours in connection with combustion gave to our science an immovable basis by fixing at once the notion of simple bodies and the essential character of chemical combinations. In these latter we find in weight all that is ponderable in their elements. These, in uniting to form compound bodies, do not lose any of their proper substance; they lose only an imponderable thing, the heat disengaged at the moment of combination. Hence that conception of Lavoisier that a simple body such as oxygen is constituted, properly speaking, by the intimate union of the ponderable matter oxygen with the imponderable fluid which constitutes the principle of heat, and which he named caloric—a profound conception, which modern science has adopted, giving it a different form. It is, then, unjust that, in recent times, Lavoisier should be accused of having misconceived what is physical in the phenomenon of combustion, and that an attempt should be made to rehabilitate the doctrine of Phlogiston which he had the honour of overturning. It is true that in burning bodies lose something: "It is the combustible principle," said the partisans of Phlogiston; "It is caloric," said Lavoisier; and he adds, an essential thing, that they gain in oxygen.

Thus Lavoisier perceived completely the phenomenon, of which the great author of the phlogiston theory, G. E. Stahl, had only a glimpse of the external appearances, and of which he misconceived the characteristic feature. Such is, gentlemen, I maintain, the foundation and the origin of modern chemistry. Is that to say that the monument raised upon these bases by Lavoisier and his contemporaries subsists in all its parts, and that it was accomplished at the end of last century? It would not be from want of materials, and even in its outlines we may notice lines which have in time disappeared. It has then been added to and in part transformed; but it still rests upon the same foundations. Such has been in all sciences and in all times the lot of theoretical conceptions; the best of them contain obscurities and gaps which, on disappearing, become the occasion of important developments or of a new generalisation.

That of Lavoisier embraced especially the bodies best known in his time, *i.e.*, the compounds of oxygen, the true nature of which was discovered by him in his researches on combustion. All these bodies are formed of two elements; their constitution is binary, but it is more or less complicated. Some, oxides or acids, contain a simple body united to oxygen; others, more complex, are formed by the combination of acids and oxides among themselves, a combination which gives rise to salts. These last then are formed of two constituent parts, each of which contains oxygen united to a simple body. Such is the formula of Lavoisier on the constitution of salts; it is in harmony with the fundamental idea which he enounced on chemical combination, an idea according to which all compound bodies are formed of two immediate elements, which are either simple bodies or themselves compound bodies.

This dualistic hypothesis was embodied, in his time and with his consent, in French nomenclature, the work of Guyton de Morveau, the principle of which may be thus summarised: two words to designate each compound, one to mark the genus, the other the species. Thus, one of the fundamental conceptions of the system of Lavoisier—dualism in combinations—found a striking expression in the binary structure of the names, and is, as it were, insinuated into the mind by the very terms of chemical language; and we know what is, in such a case, the power of words.

The great successor of Lavoisier, Berzelius, extended to the whole of chemistry the dualistic hypothesis of Lavoisier on the constitution of salts. Wishing to give it a solid support, he added to it the electro-chemical hypothesis. All bodies are formed of two constituent parts, each of which possesses, and is, as it were, animated by, two electric fluids. And as the electro-positive fluid attracts the electro-negative, it is natural, it is necessary that in every chemical compound the two elements should reciprocally attract each other. Is not the one carried towards the other by electric fluids of opposite kinds? We see that the hypothesis of Berzelius gives at once a striking interpretation of the dualism in combinations and a simple and profound theory of chemical affinity. This elective attraction which the final particles of matter exercise upon each other was referred to electric attraction.

Another theoretic conception gave a body to the electro-chemical hypothesis, and has given since a solid basis to chemistry as a whole. We speak of the atomic theory, revived from the Greeks, but which took, at the commencement of this century, a new form and a precise expression. It is due to the penetration of an English thinker, Dalton, a teacher of chemistry in Manchester in the beginning of the century. It was less a pure speculation of the mind, as were the ideas of the ancient atomists and of the philosophers of the Castesian school, than a theoretical representation of well-established facts, viz., the parity of the proportions according to which bodies combine, and the simplicity of the relations which express the multiple combinations between two bodies.

Dalton found, in fact, that, in cases where two substances combine in several proportions, if the quantity of one of them remains constant, the quantities of the other vary according to very simple relations. The discovery of this fact was the starting-point of the atomic theory. Here is the substance of this theory:—That which fills space, viz. matter, is not infinitely divisible, but is composed of a universe of invisible, imperceptible particles, which, nevertheless, possess a real extension and a definite weight. These are atoms. In their infinitely attenuated dimensions, they offer points of application to the physical and chemical forces. They are not all like each other, and the diversity of matter is owing to inherent differences in their nature. Perfectly identical for the same simple body, they differ from one element to another in their relative weights, and perhaps by their form. Affinity sets them in motion, and when two bodies combine with each other, the atoms of the one are drawn towards the atoms of the other. As this approach always takes place in the same manner between a determinate number of atoms, which are in juxtaposition one to one, or one to two, or one to three, or two to three—in other words, according to very simple proportions, but invariable for a given combination—it results therefrom that the smallest particles of this combination present a fixed composition rigorously similar to that of the entire mass.

Thus the most important fact of chemistry, the immutability of the proportions according to which bodies combine, appears as a consequence of the fundamental hypothesis that chemical combinations result from the coming together of atoms possessing invariable weights. Berzelius compared these atoms to minute magnets. He imagined them to have two poles where the two electric fluids are separated but unequally distributed, so that one of them is in excess at one of the poles. "There exists," he said, "atoms with excess of positive fluid and others with excess of negative fluid; the first attract the second, and this attraction, the source of chemical affinity, preserve the atoms under all combinations. At the moment that these last are formed they are set in motion; in the completely formed compound they are at rest, and are divided as if into two camps, at once kept together and maintained in opposition by the two electric fluids of opposite kinds.

Thus the electro-chemical theory, ingeniously adapted to the hypothesis of atoms, raised the dualism of Lavoisier to the dignity of a system, which appeared solidly established during the first half of this century. The facts then known were included in it without difficulty, and the rich materials which the patience or the genius of experimenters amassed without ceasing were very soon co-ordinated.

Without attempting to enumerate the older works relating to the decomposition of alkalis, to the nature of chlorine recognised as a simple body, to various newly-discovered elements, such as selenium, tellurium, iodine, we shall mention in a special manner among so many discoveries, that of cyanogen, which we owe to our own Gay-Lussac. The demonstration of the chemical functions of this compound gas, which behaves like a simple body, which is capable of forming the most varied combinations with true elements, which finally, when it is engaged in such combinations lends itself to double decompositions, as does chlorine in the chlorides, was a great step in the progressive march of science. Hence the definition: cyanogen is a compound radical, and the triumphant appearance of the doctrine of radicals. It had been vaguely intimated by Lavoisier; it really dates from the discovery of cyanogen, and will make a rapid advance. Up to that time great efforts had been directed to the side of inorganic chemistry, and great ideas had arisen in this domain. The application of these ideas to organic chemistry, upon which attention then began to be directed, presented some difficulties.

We know that the innumerable bodies which nature has distributed in the organs of plants and animals contain a small number of elements—carbon, hydrogen, oxygen, and often nitrogen. It is then not in their general composition that they differ, but by the number and arrangement of the atoms which enter into their composition. By increasing more or less and grouping themselves in various manners, these atoms give rise to an immense multitude of distinct compounds which are true chemical species. But what is the arrangement of these atoms? What is the structure of these organic molecules, so much alike in the nature of their elements, so wonderful in the infinite diversity of their properties? Berzelius solved this question without hesitation. Comparing organic compounds to the bodies of inorganic chemistry, he divided both classes of atoms into two lots, grouping on one side carbon and hydrogen, electro-positives, and on the other, oxygen, electro-negative. And when, at a later time, chlorine was artificially introduced into organic compounds, the atoms of this powerful element were ranged on the side of oxygen, both being invariably found in binary combinations of which they formed the electro-negative element, the atoms of carbon and hydrogen constituting the electro-positive radical.

Thus the great promoter of inorganic chemistry attempted to fashion organic molecules according to the image of those molecules of dead matter which he had studied so thoroughly. The paths which Lavoisier traced in this domain he wished to extend to the world of products formed under the influence of life; they resulted in a dead-lock. In proportion as the riches of science increased it was necessary, in order to uphold the system, to accumulate hypotheses, to invent radicals, to construct, with insufficient or imaginary data, formulæ more and more complicated—a thankless task, in which the feeling of experimental realities and sober appreciation of facts often gave place to outrageous reasonings and vague subtleties. These barren efforts of a great mind inaugurated the decline or marked the termination of the dualistic ideas which were at the foundation of what has been called, improperly perhaps, the old chemistry. The new began at that point. Great discoveries, cleverly and boldly interpreted, gave it an impulse which still endures.

There were then—I speak of forty years ago—a number of young men, with Dumas and Liebig at their head, in the opposite camp, who cultivated with ardour the investigation of organic compounds. Convinced that the constitution of these compounds could only be deduced from the attentive investigation of their properties and metamorphoses, they undertook to investigate these bodies themselves, to transform them, to torment them in some sort by the action of the most diverse reagents, in the hope of discovering their intimate structure. And this is, gentlemen, the true method in chemistry; to determine the composition of bodies, and by careful analysis of their properties to fix, as far as possible, the grouping of their ultimate particles. This, then, is the glory of our science, and the single but precious contribution which it is able to furnish for the solution of that eternal problem, the constitution of matter.

From the researches which were made at this epoch and in this spirit, an all-important fact issued; it relates to the action of chlorine on organic compounds. This simple body deprives them of hydrogen and may be substituted for that element, atom for atom, without affecting the molecular equilibrium and without, adds Dumas, modifying the fundamental properties. This proposition encountered at first the most violent contradiction. How could chlorine take the place of hydrogen and play its part in combinations? These two elements, said Berzelius, are endowed with opposite properties, and if the one is lacking the other cannot supply its place; for, in short, they are two inimical brothers, little disposed and by no means fit to be kept in the same house. These critics and many others have not prevailed against facts. The theory of substitutions has come triumphantly out of this great discussion, which marks a date in the history of our science. Its natural development has gradually introduced into it new ideas on the constitution of chemical compounds, on the mode of combination of the elements which they contain.

These ideas have come to light by various ingenious comparisons. Laurent considered organic compounds as formed of nuclei with appendages, both the one and the other admitting into their structures atoms grouped with a certain symmetry. Dumas compared them to edifices of which the atoms constitute, in a manner, the materials. Hence the graphic but frequently correct expression, of molecular edifices capable of being modified, in certain cases, by the substitution of one part for another, and which, in other cases, the shock of powerful reagents may shatter to pieces. In both conceptions the chemical molecules were regarded as forming a whole. A little later Dumas compared them to planetary systems; and here he veritably shot ahead of his time in giving us a glimpse of groups of atoms maintained in equilibrium by affinity, but carried along by movements, as the planets of a solar system are acted upon by gravitation and carried into space. It is in these movements of atoms and molecules that at a later period the source of the physical and chemical forces must be sought for; but I must not anticipate. I have attempted to show how the ideas on chemical combinations have been gradually modified under the double influence of the atomic hypotheses and of facts brought to light by the French school concerning their reciprocal replacement in combinations. Forming a whole, more or less complex, the molecules of organic substances may be modified by substitution and give rise to a multitude of derivatives which naturally attach themselves to the mother substance. The latter serves them as a model or type. The typical idea thus introduced into science very soon occupied a large place. It first brought to it important elements of classification. All the compounds derived by substitution from the same body were ranged in the same family, of which the latter was, so to speak, the chief. Hence arose groups of bodies perfectly distinct from each other, and the number of which were being constantly increased by daily discoveries. It was necessary not only to introduce order into all these tribes, but to connect them with each other by a common bond. The honour of having discovered the superior principle of classification belongs to Laurent and Gerhardt, valiant champions of French science, from whom premature death has snatched, if not victory, at least the gratification of victory. Laurent was the first to say that a certain number of mineral and organic compounds possessed the constitution of water, and this idea, brilliantly developed by Williamson, was generalised by Gerhardt. According to the last named, all inorganic and organic compounds may be connected with a small number of types, of which hydrochloric acid, water, and ammonia, are the chief. In these compounds, relatively simple, one element may be replaced by another element, or by a group of atoms performing the function of a radical, so that this substitution gives rise to a multitude of various compounds bound together by the analogy of their structure, if not by the harmony of their properties.

This last point was novel and important. Bodies belonging to one type and similar in their molecular structure may differ much in their properties: these depend not only on the arrangement of the atoms, but also on their nature. Thus the inorganic and organic bodies ranged under the type water, are, according to the nature of their elements or their radicals, powerful bases, energetic acids, or indifferent substances—a great and bold idea, which has established a connection between the most diverse bodies, and which has definitely overturned the barriers which use had raised, and which the weakness of theory had maintained, between inorganic and organic chemistry. And yet this was only a stage in the march of ideas. By what right and by what privilege, it was said, may the relatively simple compounds we have named serve as types for all others, and why should nature be restricted to make all bodies on the model of hydrochloric acid, water, and ammonia? This was a serious difficulty, but it has been removed; it became the occasion of a profound discussion and the germ of a real progress.

These typical compounds represent at bottom various forms of combination, the diversity of which it is necessary to refer to the nature of the elements themselves. The latter impress on each of these compound types a particular character and a special form. The atoms of chlorine are so formed that to one of them only a single atom of hydrogen needs to be added to form hydrochloric acid; then that an atom of oxygen takes two atoms of hydrogen to form water; that an atom of nitrogen requires three to constitute ammonium; and that an atom of carbon demands four to become marsh-gas. What a difference in the power of combination of these elements, and, so to speak, in their appetites for hydrogen! And will this difference not be connected with some peculiarities in their mode of existence, to some property inherent in matter itself, and which will impress on each of these hydrogenic compounds a special form? Such is the case.

It is now admitted that atoms are not motionless, even in bodies apparently the most fixed and in completely formed combinations. At the moment when these are being formed the atoms come into violent collision with each other. In this conflict a disengagement of heat is ordinarily observed, resulting from the expenditure of active energy which the atoms have lost in the *mêlée*, and the intensity of this heat-phenomenon gives the measure of the energy of the affinities which have presided at the combination. But there is another thing in chemical phenomena besides the intensity of the forces at work, and which are more or less exhausted by a disengagement of heat; I refer to their *mode*; it was of this elective attraction that Bergman spoke a century ago, and which governs the form of the combinations. The atoms of the various simple bodies are not endowed with the same aptitude for combination with each other ; they are not equivalent to each other. This is what is called atomicity, and the fundamental property of atoms is without doubt connected with the various modes of motion by which they are animated. When these atoms combine with each other, their movements require to be reciprocally co-ordinated, and this co-ordination determines the form of the new systems of equilibrium which will be formed ; that is, the new combinations.

It is with atoms thus endowed that chemists now construct molecular edifices. Resting at once upon the data of analysis and on the investigation of reactions, they express the composition of bodies by formulæ which mark the nature, the number, and the arrangement of the atoms which each molecule of these bodies contains. But what ! is this merely an ingenious exercise of the mind ? and the construction of formulæ by means of these symbolic materials which are selected, which are arranged so as to give to the molecular edifice a determined form,—is this a mere matter of curiosity ? By no means. These formulæ, by whose aid are expressed the composition of bodies and the constitution of their molecules, offer also a valuable aid for the interpretation of their properties, for the study of their metamorphoses, for the discovery of their reciprocal relations,—all things which are intimately connected in each body with the nature and arrangement of the atoms. Now, the investigation and comparison of these formulæ furnish to the inquiring spirit the elements of a powerful synthesis. What treasures have been acquired by science by this process, which consists in deducing the transformations of bodies from their molecular structure, and in creating, by a sort of intuition, new molecules by means of those already known ! The artificial formation of a number of combinations, the syntheses of as many organic compounds as nature alone seemed to have the privilege of forming—in a word, the greater part of chemical discoveries which have enriched science and the world for twenty years—are founded on this inductive method, the only efficacious and the only rational one in the sciences. I shall cite only one example among many others.

A happy chance led to the discovery of that brilliant substance, of a bright purple, which is known under the name of fuchsine or rosaniline. Analysis determines its composition, skilled investigations find its molecular structure. Soon it is known how to modify it, to multiply the number of its derivatives, to vary the sources of their production, and from attentive study of all these reactions, issue a pleiad of analogous substances whose diverse colours rival in brilliancy the richest tints of the rainbow. A new and powerful industry has already resulted from all these investigations, which theory has followed step by step and guided the fertile evolution. In this order of investigation, science has recently gained one of her most striking triumphs. She has succeeded in forming at once the colouring matter of madder (alizarin). By an ingenious combination of reactions, and by theoretic reasonings still more ingenious, MM. Graebe and Liebermann have succeeded in obtaining this body synthetically, by means of anthracene, one of the numerous bodies which is now obtained from coal-tar, the impure source of so many wonders. Such is a discovery which has issued from the womb of science, and of science the most abstract ; confirming preconceived ideas on the relations of composition and of atomic structure between anthracene, alizarin, and the intermediate terms. And this will not be the last product of this beautiful development of chemistry. Future conceptions on the intimate structure of complex organic compounds will be so many landmarks for new syntheses, and hypotheses rigorously deduced from acquired principles will be fruitful in the happiest applications.

Saccharine matters, alkaloids, other complex bodies whose properties and diverse transformations are actively investigated with a view of deducing their molecular constitution—all these substances may be artificially reproduced, as soon as this preparatory work, so difficult and often seemingly so useless, will have sufficiently advanced. So fine a programme justifies the great efforts which have been made, in our days, in this direction. To discover, to analyse, to study, to classify, to reproduce artificially so many diverse substances, to study their internal structure, to indicate their useful applications ; to surprise, in a word, the secrets of Nature and to imitate her, if not in her processes, at least in some of her productions—such is the noble aim of contemporary science. She can only reach it by the sure but slow paths we have indicated ; experiment guided by theory. In chemistry, at least, empiricism has had its day ; problems, clearly stated, must be boldly faced, and henceforth the rational conquests of experiment will only leave a place more and more circumscribed for fortunate finds and the surprises of the crucible. Away, then, with the detractors of theory, who go in quest of discoveries which they can neither foresee nor prepare ; they reap where they have not sown. But you, courageous workers, who trace methodically your furrows, I congratulate you. You may be sometimes deceived, but your work will be fruitful, and the goods which you amass will be the true treasure of science .

Will not this science be one day embarrassed and as if encumbered with so much riches, and will the strongest memory be able to support all the weight ? If the danger exists, there is no need to fear it. The classification of all these materials will free us from embarrassment. In a well-arranged edifice, each stone requires to be prepared before taking its place ; but the consruction accomplished, all do not strike the eye equally, though each has its use ; only the strong courses, the corner-stones and the salient parts, are noticed. It will be thus with the monument of science. The details which have for their end to fill up gaps will disappear in the great whole, of which we only need consider the foundation, the principal lines, and the crowning of the edifice.

Gentlemen, chemistry thus constituted, and physics, have between them necessary connections. Both the one and the other investigate the properties of bodies, and it is evident that, so far as the ponderable bodies are concerned, these properties must be intimately connected with the constitution of matter. Hence the atomic hypothesis which suffices for the interpretation of chemical phenomena ought also to be adapted to physical theories. This is the case. It is in the movements of atoms and of molecules that we now seek, not only the source of the chemical forces, but the cause of the physical modifications of matter, changes of condition which it can undergo, phenomena of light, of heat, of electricity, of which it is the support.

Two French *savans*, Dulong and Petit, discovered some time ago a very simple law which connects the weights of atoms with their specific heats. It is known that the quantities of heat necessary to change by one degree the temperature of the unit of weight of bodies are very unequal. This is what we call specific heats ; but the quantities of heat which bring about in simple bodies, taken under conditions in which they are rigorously comparable, the same variations of temperatures, are equal, if we apply these quantities of heat not to the unit of weight but to the atomic weight ; in other words, the atoms of these elementary bodies possess the same specific heats, though their relative weights are very unequal.

But as to this heat which is thus communicated to them, and which raises their temperature equally, what is in reality its mode of action ? It augments the intensity of their vibratory movements. Physicists recognise heat as a mode of motion, and that it comes under the cognisance of our perceptions by the vibrations of atomic matter or ether ; of ether, that fluid material perfectly elastic, incoercible, imponderable, which fills all the immensity of space and the depth of all bodies. It is in this fluid that the stars describe their orbits ; in this fluid atoms perform their movements and describe their trajectories. Thus the ether, the radiant messenger of heat and light, conveys and distributes their radiations through all the universe ; and that which it loses in vibratory energy when it penetrates a cold body, which it warms, it communicates to the atoms of this body and augments the intensity of their movements ; and that which it gains in energy by contact with a warm body, which it cools, it withdraws from this body and diminishes the intensity of their vibratory movements. And this kind of light and heat which come from material bodies is transmitted across space to other material bodies. You will remember in reference to this the words which Goethe put into the mouth of the Prince of Darkness in cursing the light—" It is born of bodies, it is brought forth and maintained by bodies, and it will perish with them."

But this exchange of forces which circulate from ether to atoms and from atoms to ether, must it manifest itself always in the phenomena of light or heat ? This vibratory force which is transmitted by ether, can it not be preserved and stored up by matter, or appear under other forms ?

It can be preserved as affinity, liberated as electricity, transformed into dynamic movements. It is this which is stored up in the innumerable compounds elaborated by the vegetable kingdom ; it is this which provokes the decomposition of carbonic acid and of the vapour of water by the most delicate organs of plants which blossom in the sunlight. Originating with the sun, luminous radiation becomes affinity in the immediate organic principles which are formed and accumulated in vegetable cellules. That mode of motion of ether which was "light" is become another mode of motion which is "affinity," and sways the atoms of an organic compound. In its turn this force thus stored up is expended again when the organic compounds are destroyed in the phenomena of combustion. Affinity, satisfied and as it were lost by the combination of combustible elements with oxygen, again becomes heat or electricity. Wood in burning, and carbon in becoming oxidised, produce sparks or flames: a metal which exhausts its affinities in decomposing an acid warms the liquid, or, under other conditions, produces an electric current, warming it less when the current is exterior. And in another order of phenomena, heat which distributes or propagates itself unequally between two surfaces, rubbing one against the other, or in a crystal that is warmed, or in two metals united by solder, disappears partially as such and manifests itself as static electricity or as an electric current. Thus all these forces are equivalent to one another and appear under diverse forms, whether they are passing from atoms to ether or from ether to atoms; but we never see them disappear or lose their force—only transform themselves and perpetually renew their youth.

And this is not all. These vibratory movements which sway atoms and which whirl about in ether can cause movements of the mass, displacement either of the bodies or of the molecules. Warm a bar of iron, it will dilate with a force almost irresistible; a part of the heat will be employed in producing a certain pulling asunder of the molecules. Warm a gas, it will in like way dilate, and a part of the heat disappearing as such, will produce a separation very considerable in this case between the gaseous molecules; and the proof of the consumption of heat in the work of dilation is not difficult to give, for if you warm the same gas to the same degree, but prevent it from dilating, less heat need be given to it than in the former case. The difference between the two quantities of heat corresponds exactly to the mechanical work performed by the molecules in dilatation. That is one of the most simple considerations, on which is founded the principle of the mechanical equivalent of heat so often now referred to in mechanics, in physics, and in physiology.

In physics it explains the mystery of latent heat, of fusion, and of volatilisation. But how is it that heat supplied continuously to a boiling liquid to maintain ebullition does not ever raise the temperature of the liquid above a point which under similar pressure remains fixed? The reason is that this heat is continually absorbed, and disappears as such to produce the mechanical work of driving apart the molecules. And so in the phenomena of fusion, the constancy of the temperature indicates the absorption of the heat consumed in molecular work. These conceptions have modified and thrown much light on the definitions which physicists have applied to different states of matter, and it is seen that they are in harmony with chemical theories of the constitution of bodies. These are formed of molecules which represent systems of atoms animated by harmonic movements, and whose equilibrium is exactly maintained and strengthened by these movements.

Applied to molecules thus constituted, heat can produce three different effects. In the first place, an elevation of temperature by the increase of vibratory energy; in the second place, an increase of volume by the driving apart of atoms and molecules, and this augmentation becoming very considerable, a change of condition, solid becoming liquid, and liquid becoming gas; in the last, the driving apart of the molecules is become immense in relation to their dimensions. Thus acting on the atoms which compose the molecule and amplifying their trajectories, heat can disturb the equilibrium which exists in the system, causing a conflict of these atoms with those of another molecule in such a way that this disturbance or this conflict leads to fresh systems of equilibrium, that is to new molecules. There commence the phenomena of decomposition and dissociation, or, inversely, of combination, which is the mainspring of chemistry, and it is seen they are but the continuation or consequence of the physical phenomena we have just analysed, the same hypothesis, that of atoms, applied to one and the other with an equal simplicity.

I ask, will it not be easy to conceive that the physical and chemical forces which act on ponderable bodies are applied also to diffuse continuous matter in some way, and is it not natural to suppose that there are limited and definite particles which represent the points of application of all these forces? And this view ought to apply to the two sorts of matter which form the universe, ether and atomic matter, the one infinitely rarefied but homogeneous, filling all space, and in consequence enormous in its mass, both unseizable and imponderable; the other non-continuous, heterogeneous, and only occupying a very limited portion of space, although it forms all worlds.

Yes, it forms all worlds, and the elements of ours have been discovered in the sun and in the stars. Yes, the radiations given off by incandescent atomic matter which forms these stars are also, for the most part, those which are prodnced by the simple bodies of our planet. Marvellous conquest of physics which reveals at once to us the abundance of forces which environ the sun and the simplicity of the constitution of the universe!

A solar ray falls upon a prism and is turned aside in its path and decomposed into an infinity of different radiations. These take each a particular direction, and all range themselves in bands in juxtaposition, and spread themselves out in the spectrum if the light thus received and decomposed is thrown on to a screen. The visible part of this spectrum shines with all the colours of the rainbow; but besides this, beyond both ends of the coloured bands the radiations are not absent. The heat-rays can be made to reveal themselves beyond the red; the chemical rays, more powerful than the others to make and destroy the chemical combinations, are known beyond the violet. All the forces which manifest themselves on the surface of our globe, as heat, light, and chemical energy, are sent to us in a ray of white light.

But this brilliant spectrum is not continuous. Fraunhofer has discovered in it an infinity of black lines cutting the shining band; these are the "dark lines" of the spectrum, and Kirchhoff has found that a certain number of them occupy the same position as the "bright lines" which occur in the spectra of metallic substances when in a state of incandescence. This last physicist, generalising an observation of Foucault, has seen, further, that under given circumstances these bright lines can be obscured and "reversed," coinciding then with the dark lines of the solar spectrum.

We have been able to conclude that these have an identical origin and are due to radiations given off by metallic substances spread in vapour over the solar globe, radiations which are obscured by these same vapours in the atmosphere of the sun. Thus the star which gives us heat, light, and life, is formed of elements like those which form our globe. These elements are hydrogen and metals in a state of vapour. They are not distributed equally in the mass of the sun and in his rarefied envelopes; the hydrogen and most volatile metals are raised to a greater height on the surface of the sun than are the other metals. They are never in repose; this ocean of incandescent gas is continually agitated by tremendous tempests. The *trombes* throw themselves out in immense columns to the height of 50,000 leagues above the gaseous sphere; these are the "protuberances," and they shine with a rose light peculiar to themselves; and they are formed according to Janssen and Lockyer by hydrogen, very rarefied, and also by an unknown substance—"helium." The luminous globe itself, the photosphere, gives the spectra of our ordinary metals, except gold, silver, platinum, and mercury; the precious metals, those which have little affinity for oxygen, being wanting. But, on the contrary, in the solar spectrum there are "lines" different from those which the metals of our earth give, but which are like them. The lines of the metalloids are wanting, as are the lines which are characteristic of compound bodies. The gaseous mass has such an incandescence that no chemical combination could withstand it.

The lines of Fraunhofer are dark, only the lines of the protuberances and those seen a moment after the disappearance of the sun in an eclipse, and a moment before its reappearance, are bright, like those which characterise the spectra of incandescent metallic vapours. Here we have a curious relationship which has furnished most important and precise indications on the physical constitution of the sun.

I have spoken of the chemistry of the sun, but the spectroscope has explored all the far-off space of heaven. The light of hundreds of stars has been analysed, and nebulæ, scarcely visible, have had the quality of their radiations revealed by its aid. The light, in some cases very feeble, with which a number of stars shine, gives a spectrum with dark lines like the solar spectrum, and this fact proves to us that the constitution of these stars is like that of our sun. Aldebaran sends us records of hydrogen, magnesium, and calcium, which abound in solar light, but also those of metals which are rare or absent, as tellurium, antimony, and mercury.

Nebulæ, twenty thousand times less brilliant than a candle a a distance of 400 metres, have still given a spectrum, for their light, although feeble, is very simple in its constitution, and the spectrum which it gives consists only of two or three bright bands, one of hydrogen, the other of nitrogen. These nebulæ which give a spectrum of bright lines, are those which the most powerful telescopes cannot resolve : there is an "abyss" between them and resolvable nebulæ, which, like ordinary stars, give a spectrum with dark lines.

What an effort of the human mind ! To discover the constitution of stars of which the distances even are unknown; of nebulæ which are not yet worlds ; to establish a classification of all the stars, and still more to guess their ages—ah, tell me, is not this a triumph for science ? Yes, we have classed them according to their ages. Stars coloured, stars yellow, stars white ; the white are the hottest and the youngest ; their spectrum is composed of a few lines only, and these lines are dark. Hydrogen predominates. Traces of magnesium are also met with, of iron, and perhaps of sodium, and if it is true that Sirius was a red star in the time of the ancients, it owed perhaps its tint to the greater abundance of hydrogen at that epoch. Our sun, Aldebaran, Arcturus, are among the yellow stars. In their spectra the hydrogen lines are less developed, but the metallic lines are fine and numerous. The coloured stars are not so hot, and are older. In consequence of their age they emit less vivid light. In them there is little or no hydrogen. Metallic lines abound, but one also finds channelled spaces like the lines of compounds. The temperature being lower, these latter can exist whether they consist of atoms joined to others of the same kind, or whether they contain groups of heterogeneous atoms. In referring recently to this classification of Father Secchi and the distribution of simple bodies in distant stars, Lockyer has observed that the elements the atoms of which are lightest are to be found in the hottest stars, and that the metals with high atomic weights are, on the contrary, met with in the colder stars ; and he adds this—Are not the first elements the result of a decomposition brought about by the extreme temperatures to which the latter are exposed, and, taking them altogether, are they not the product of a condensation of very light atoms of an unknown primordial matter, which is perhaps ether ?

Thus is brought forward afresh, from considerations taken from the constitution of the universe, this question of the unity of matter which chemistry has before raised from a consideration of the relative weight of atoms. It is not solved, and it is probable that it never will be in the sense here indicated. Everything leads to the belief in the diversity of matter, and the indestructible, irreducible nature of atoms. Does it not require, as M. Berthelot has pointed out, the same quantity of heat to put them in motion, whether they are heavy or light, and ought not the law of Petit and Dulong to prevail in its simplicity against the opposite hypothesis, however ingenious it may be ?

I have endeavoured, gentlemen, to trace out for you the most recent progress accomplished in chemistry, in physics, and in physical astronomy, sciences so diverse in their object, but which have a basis in common—matter—and one supreme object—a knowledge of its constitution and of its properties and of its distribution in the universe. They teach us that the worlds which people infinite space are made like our own system, and that this great universe is all movement, co-ordinated movement. But new and marvellous fact, this harmony of the celestial spheres of which Pythagoras spoke, and which a modern poet has celebrated in immortal verse, is met with in the world of the infinitely little. There also all is co-ordinated movement, and these atoms, whose accumulation forms matter, have never any repose ; a grain of dust is full of innumerable multitudes of material unities each of which is agitated by movements. All vibrates in the little world, and this universal restlessness of matter, this "atomic music," to continue the metaphor of the ancient philosopher, is like the harmony of worlds ; and is it not true that the imagination is equally bewildered and the spirit equally troubled by the spectacle of the illimitable immensity of the universe and by the consideration of the millions of atoms which people a drop of water. Hear the words of Pascal : "I wish to picture not only the visible universe, but the immensity of nature that one can conceive within the limits of an atom ; one may picture there an infinity of worlds, where each has its firmament, as in the visible universe."

As to matter, it is everywhere the same, and the hydrogen of water we meet with in our sun, in Sirius, and in the nebulæ, everywhere it moves, everywhere it vibrates, and these movements which appear to us inseparable from atoms, are also the origin of all physical and chemical force.

Such is the order of nature, and as science penetrates it further, she brings to light both the simplicity of the means set at work and the infinite variety of the results. Thus, through the corner of the veil we have been permitted to raise, she enables us to see both the harmony and the profundity of the plan of the universe. Then we enter on another domain which the human spirit will be always impelled to enter and explore. It is thus, and you cannot change it. It is in vain that science has revealed to it the structure of the world and the order of all the phenomena ; it wishes to mount higher, and in the conviction that things have not in themselves their own *raison d'être*, their support and their origin, it is led to subject them to a first cause—unique, universal God.

SCIENTIFIC SERIALS

THE *Mittheilungen aus dem Göttingen Anthropologischen Vereine*, which are edited by Dr. Hermann von Jhering, promise to give important contributions to the department of anthropological science, and the appearance of these selections from the Transactions of the Society will be hailed with satisfaction. The first number contains an interesting paper on the origin of our knowledge of iron and bronze in Europe, by Prof. F. W. Unger, in which the author considers *seriatim* (1) the application of bronze for religious or sacrificial objects ; (2) the linguistic affinity of the terms for ores, or metal generally, in different languages ; (3-6) the mythical references to their use, seat of original works and the modes of employing bronze for and in connection with ceremonies of cremation. The section under which Prof. Unger treats of the myths and sagas connected with the history of the discovery and the first working of metals is especially interesting in regard to the early knowledge of iron possessed by the Tschudi, or primitive people of the Altai, through whom he believes that the Indo-Germanic races derived their acquaintance with its sources and modes of working.—A paper on skulls of extreme breadth, by Dr. von Jhering, which is rather a compendium of what has been done towards the definition of normal and abnormal types than a contribution of original matter, is aptly supplemented by the description of a new craniometer, given in the concluding extracts of the Transactions by Dr. W. Sprengel, who draws attention to the important direction taken by craniometrical inquiries in the course of the last year by the introduction of Dr. von Jhering's horizontal-plane apparatus, of which plates and detailed explanations are appended by the writer.—In a paper on the very widely-spread custom of tattooing the human body, in which some inquirers have believed they could trace the earliest origin of the art of using graved and written characters to express ideas, Herr Krause considers whether in this far-extending practice we have not an argument in favour of the unity of the human race. The author is not of opinion that we are justified in accepting this suggestion as capable of proof, but he thinks that this practice, against which Moses warned the Israelites, had a far higher significance than that of mere personal ornamentation, and was probably at one time or other associated with the religion of the several peoples who adopted it, while it also served as an emblematic emblasonment of the pretensions or calling of the wearer, a talismanic or hieroglyphic form of speech, and as a permanent pictorial exponent of facts in the absence of any other written language.

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